Neuromuscular blockade monitoring. A survey study

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Background: Neuromuscular blocking agents are widely used in anesthesiology to facilitate procedures such as tracheal intubation and to improve surgical conditions in specialties including vascular surgery. Neuromuscular blockade monitoring allows dose adjustment, assessment of recovery, and prevention of residual neuromuscular paralysis. However, international studies have shown that its routine use is not widespread.
Objective: The aim of this study was to determine the proportion of Mexican anesthesiologists who routinely use neuromuscular blockade monitoring and to identify associated sociodemographic factors.
Materials and Methods: A 13-item survey was administered to 100 anesthesiologists during a medical course held in Mexico City in 2024.
Results: Only 32% of participants reported routine use of neuromuscular blockade monitoring, with train-of-four being the most commonly employed method. Among anesthesiologists who did not use monitoring routinely, 91.3% expressed willingness to adopt it in the future. Rocuronium was the most frequently used neuromuscular blocking agent, and sugammadex was the most common reversal agent. Only 16.2% reported always reversing neuromuscular blockade.
Conclusion: Despite strong evidence supporting its importance, neuromuscular blockade monitoring is not yet routinely implemented in clinical practice. The willingness to adopt this practice suggests a significant opportunity to improve anesthetic care.

Keywords: BNM, TOF, sugammadex, rocuronium

Neuromuscular blocking agents (NMBAs) are routinely used in anesthesiology and intensive care to facilitate endotracheal intubation, optimize ventilatory mechanics, and improve surgical conditions [1]. These drugs are classified as depolarizing agents, such as succinylcholine, and nondepolarizing agents, including benzylisoquinoliniums such as cisatracurium and steroidal derivatives such as rocuronium [2]. Reversal of their effects is achieved with agents such as neostigmine and sugammadex. The latter is a γ-cyclodextrin capable of encapsulating approximately 90% of rocuronium and 70% of vecuronium, with dosing ranging from 1 to 16 mg/kg depending on the depth of neuromuscular blockade [3]. Neostigmine, in contrast, is a reversible acetylcholinesterase inhibitor and is effective for mild to moderate blockade, but has limited efficacy in profound blockade [4].

Since 1970, when Ali et al. introduced train-of-four (TOF) monitoring, quantitative neuromuscular monitoring has enabled objective assessment of blockade depth [5]. TOF consists of delivering four electrical stimuli at 2 Hz; the ratio of the fourth to the first response (TOF ratio, TOFR) reflects the degree of neuromuscular recovery, with values ranging from 0 to 1 [1]. This can be measured using mechanomyography, kinemyography, electromyography, and acceleromyography, the latter being the most widely used technique, typically assessing contraction of the adductor pollicis muscle [5].

Residual neuromuscular blockade, classically defined as a TOFR < 0.7, is a frequent complication associated with NMBA use and is linked to adverse events such as hypoxemia, muscle weakness, and respiratory failure. Reported incidence varies widely, from 5% to 85%, representing a clinically relevant problem [6]. Multiple clinical trials have shown that intraoperative quantitative monitoring significantly reduces the incidence of residual blockade and postoperative respiratory complications, while also optimizing NMBA and reversal-agent dosing [5,7]. In contrast, traditional clinical tests to assess neuromuscular recovery have proven unreliable, as

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Item	Response
1. Sex	Male / Female
2. Age	Years (n)
3. Training sector in anesthesiology	Public sector / Private sector
4. Years in anesthesiology practice	Years (n)
5. Current practice sector in anesthesiology	Public sector / Private sector / Both
6. Do you routinely use neuromuscular blockade monitoring?	Yes / No
7. Why do you use it routinely? (Multiple responses)	I understand how it works / I know its utility and patient benefits / To adjust reversal dosing correctly / To reduce residual neuromuscular blockade / I was trained to use it during residency / I have access to the technology
8. Why do you not use it routinely?	I rely on pharmacokinetics and pharmacodynamics / I do not know how it works / I was not trained during residency / It may cause pain / It is costly / I always reverse the NMBA / I use clinical parameters / I do not have access to the technology / I primarily practice regional anesthesia / Depending on the type of surgery
9. What type of neuromuscular monitoring do you use?	Train-of-four / Post-tetanic count / Peripheral nerve stimulator / Other
10. Would you be willing to use neuromuscular monitoring in the future?	Yes / No / I already use it
11. Which NMBA do you use most often?	Rocuronium / Vecuronium / Cisatracurium / Atracurium / Other
12. When you use NMBAs, how often do you reverse them?	Always / Sometimes / Depending on the situation / Never
13. Which medication do you use to reverse neuromuscular blockade?	Sugammadex / Neostigmine / Other

Table 1. Survey instrument.

they may be present even with TOFR values below 0.7 [8]. In response to this evidence, the American Society of Anesthesiologists and the European Society of Anaesthesiology and Intensive Care recommend routine quantitative monitoring from anesthetic induction through extubation [7]. However, multiple international surveys show limited adoption of this practice, with marked regional differences [6,9,11]. In Mexico, available information is scarce and suggests particularly low utilization of neuromuscular monitoring [11].

Given the lack of current data in the Mexican population, this study was conducted to determine the proportion of anesthesiologists who routinely use neuromuscular blockade monitoring and to explore sociodemographic factors associated with its use.

Methods

The instrument was a 13-item survey (Table 1) developed by the authors, reviewed by anesthesiologists with research expertise, and validated through a pilot test. It was administered in printed format to participants after verbal consent; the study objective was explained and confidentiality was ensured, in accordance with the bioethical principles of justice and beneficence.

The survey was administered to 100 anesthesiologists during the 50th Annual Refresher Course in Anesthesiology and Perioperative Medicine of the Mexican College of Anesthesiology, held in Mexico City from July 2 to July 6, 2024. This was a cross-sectional, descriptive, observational study. The sample size (n = 100) was calculated based on a finite population and selected by convenience sampling. Data were entered into Microsoft Excel LTSC Professional Plus 2021.

Active anesthesiologists who were at least one year post-completion of residency and agreed to complete the questionnaire were included. Non-anesthesiologists, residents, physicians with less than one year since graduation or without active clinical practice, and incomplete or non-interpretable questionnaires were excluded.

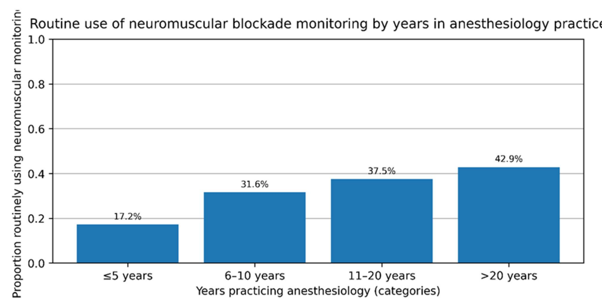

Figure 1. Proportion of anesthesiologists reporting monitoring use, stratified by years of professional practice.

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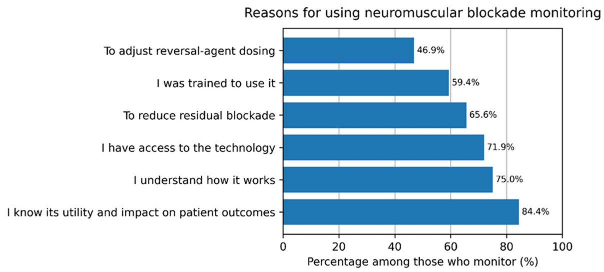

Figure 2. Reported reasons for using neuromuscular monitoring, shown as the percentage of respondents who selected each reason.

Statistical Analysis

Categorical variables were described using absolute frequencies and percentages, and continuous variables as mean and standard deviation (SD). Associations between sociodemographic variables and routine use of neuromuscular blockade monitoring were assessed using the chi-square test of independence or Fisher's exact test, depending on expected cell counts. Continuous variables (age and years of professional practice) were compared between respondents who did and did not routinely use monitoring using Student's t-test for independent samples, applying Welch's correction when necessary. The proportion of anesthesiologists reporting routine neuromuscular monitoring was estimated and compared with a reference value of 50% using a two-sided binomial test. Distributions of monitoring type, NMBA used, and reversal agent employed were compared against a theoretical uniform distribution using the chi-square goodness-of-fit test. All analyses used a statistical significance threshold of $p < 0.05$ and were performed using SPSS Statistics version 28.0.1.

Results

A total of 100 anesthesiologists were included; 55 were men and 45 were women. Participant age ranged from 29 to 75 years, with a mean of 45.5 years (SD ± 12.2). When evaluating the association between sociodemographic variables and routine use of neuromuscular blockade monitoring, p-values were as follows: sex ($p = 0.093$), training sector ($p = 0.438$),

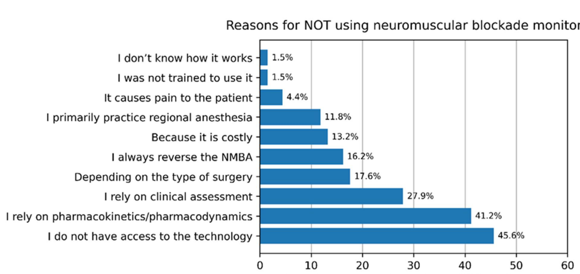

Figure 3. Reported reasons for not using neuromuscular monitoring, shown as percentages.

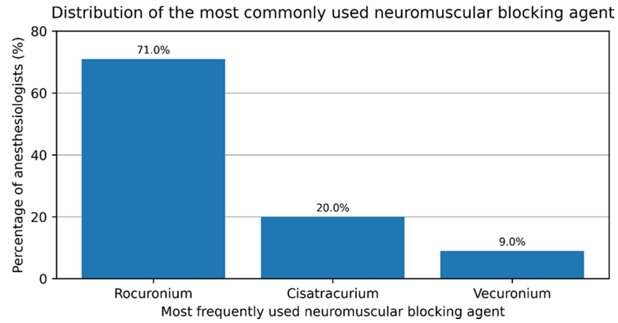

Figure 4. Distribution of neuromuscular blocking agents, shown as percentages.

practice sector ($p = 0.964$), age ($p = 0.053$), and years in anesthesiology practice ($p = 0.044$). Only years of professional practice showed a statistically significant association with routine monitoring use (Figure 1).
Overall, 32 anesthesiologists (32%) reported routine use of neuromuscular blockade monitoring. A two-sided binomial test, compared with a theoretical proportion of 50%, demonstrated a statistically significant difference ($p = 0.0004$). The most commonly used monitoring method was TOF. The chi-square goodness-of-fit test versus a theoretical uniform distribution showed a statistically significant difference in frequency of use across monitoring types ($p = 0.0007$) (Figure 2).

Reasons for using monitoring are shown in Figure 3; the most frequently reported was awareness of its utility and its impact on patient outcomes. Among reasons for not using monitoring, lack of access to the technology showed the strongest association ($p = 0.0$) (Figure 4). The most commonly used NMBA was rocuronium ($p = 0.0$), and the most frequently used reversal agent was sugammadex ($p = 0.0$); both differed significantly in chi-square goodness-of-fit testing (Figures 5 and 6).

Discussion

The findings of this study show that only about one third of the surveyed anesthesiologists routinely use neuromuscular blockade monitoring. This result contrasts with international guideline recommendations, which promote systematic use of quantitative monitoring to reduce the risk of residual

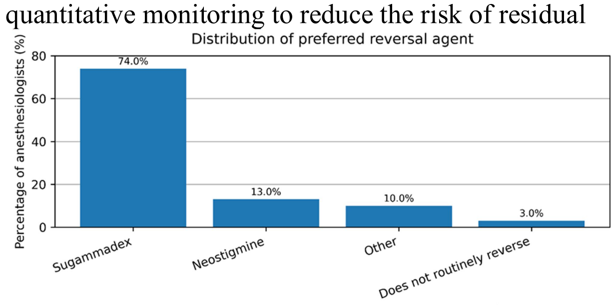

Figure 5. Distribution of preferred agents for reversal of neuromuscular blockade, shown as percentages.

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neuromuscular blockade and its associated complications [7]. Nevertheless, multiple studies have documented limited implementation of this tool in daily clinical practice, largely due to limited availability of the technology in the workplace, a finding similar to that reported by Naguib et al. in 2010 [9]. Our results are consistent with previous studies conducted in Europe and Mexico, which have shown low adoption of neuromuscular monitoring despite its well-recognized importance for patient safety [9,11].

Among respondents who do use this tool, TOF was the most frequently used method, in line with current guidelines that recommend it due to its sensitivity and its ability to objectively quantify the degree of neuromuscular blockade [1,7]. A relevant finding was that fewer than 20% of participants reported systematically reversing neuromuscular blockade at the end of surgery, which could increase the risk of postoperative residual paralysis, a condition associated with increased morbidity and mortality [6]. From a statistical standpoint, a significant association was observed between routine monitoring use and age, as well as years in professional practice, suggesting that greater clinical experience may negatively influence adoption of evidence-based practices. In contrast, sex, training sector, and workplace setting were not significantly associated. An encouraging aspect was that most anesthesiologists who do not currently use monitoring reported willingness to implement it in the future. However, as noted by Brull et al., changing entrenched clinical practices is challenging, particularly when neuromuscular management has historically relied on subjective assessments [12]. This willingness represents an opportunity to promote educational strategies, continuing training, and institutional policies that support safer anesthetic practice.

Conclusion

Despite the limited sample size, the results of this study are consistent with the available literature and confirm that routine neuromuscular blockade monitoring has not yet been fully integrated into daily clinical practice, despite its demonstrated clinical benefits and endorsement by multiple international societies. The observed association between older age and more years of professional experience with lower adoption of this tool suggests that quality-improvement strategies should target both senior anesthesiologists and those in training. In this context, improving access to monitoring devices, incorporating their use into institutional protocols, and strengthening continuing medical education may facilitate broader and more sustained implementation. These actions would help advance toward safer anesthetic practice aligned with international recommendations, benefiting both patients and healthcare personnel.

Conflicts of interests

The authors declare no conflict of interest.

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